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InGaAsP avalanche photodetectors for non-gated 1.06 um photon-counting receivers

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The efficient detection of single photons at 1.06 um is of considerable interest for lidar/ladar systems designed for remote sensing and ranging as well as for free-space optical transmission in photon-starved applications. However, silicon-based single photon avalanche diodes (SPADs) used at shorter wavelengths have very low single photon detection efficiency (~1 – 2%) at 1.06 um, and InP/InGaAs SPADs designed for telecommunications wavelengths near 1.5 um exhibit high dark count rates that generally inhibit non-gated (free-running) operation. To bridge this "single photon detection gap" for wavelengths just beyond 1 um, we have developed high performance, large area (80 – 200 um diameter) InP-based InGaAsP quaternary absorber SPADs optimized for operation at 1.06 um and based on a highly reliable planar geometry avalanche photodiode structure. We will show that dark count rates are sufficiently low to allow for non-gated operation while achieving detection efficiencies far surpassing those found for Si SPADs. At a detection efficiency of 10%, 80 um diameter devices exhibit dark count rates below 1000 Hz and count rates of at least 3 MHz when operated at -40 C. Significantly higher detection efficiencies (30 – 50%) are achievable with acceptable tradeoffs in dark count rate. In this paper, we will also discuss performance modeling for these devices and compare their behavior with longer wavelength InP-based InGaAs ternary absorber SPADs fabricated on a related device design platform.